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Morphological measurements of a short-toed eagle chick (*Circuaeus Gallicus*) during the nesting period: A study to analyze growth rates, Al-Jabal Al-Akhdar -Libya.

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Highlights

- **Conducted over five consecutive breeding seasons (2020–2024) in Libya's Wadi Al-Naqa Reserve, this study tracks the morphological development of short-toed eagle chicks (Circaetus gallicus) during the nesting period.**
- **Statistical analysis reveals that the chicks' growth rate increases significantly after 45 days post-hatching, reaching maximum averages of 31 cm in length, 24 cm in width, 1.7 kg in weight, 19 cm in leg length, and 2.7 cm in claw length.**
- **Strong positive correlations were identified across all measured body traits, providing vital baseline biometric data to assess raptor development and ecosystem health in the Al-Jabal Al-Akhdar region.**

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ABSTRACT

This study, conducted in the Wadi Al-Naqa reserve in the Al-Jabal Al-Akhdar region of eastern Libya, monitored the morphological development of a short-toed eagle chick over five consecutive breeding seasons (2020-2024 AD). Measurements of length, width, weight, claw length, and leg length were taken using a measuring tape and an electronic scale during the nesting period and were analyzed statistically. The results revealed that the chick's growth increased significantly after 45 days post-hatching, with maximum average measurements reaching 31cm (length), 24 cm (width), 1.7 kg (weight), 2.7 cm (claw length), and 19cm (leg length). The greatest annual increase in length, width, weight, and leg length occurred in 2021, while the largest increase in claw length was recorded in 2024. A strong positive correlation was identified among all morphological characteristics. These findings provide a detailed analysis of the growth and developmental trajectory of a short-toed eagle chick.

1. Introduction

The measurement of morphological traits is important for the study of taxonomic and sexual differences. Factors such as sex, age, and species of birds cause significant variation in morphometric measurements (Töpfer, 2018). Wild animals and birds are also affected by changes in their environment, such as drought, climate extremes, and human activities, which impact their reproductive success (Elshatshat *et al.,* 2024). Ecogeography can fundamentally affect certain traits (Sun et al., 2017; Winkler and Leisler, 2005). Morphological variation is the result of evolutionary and adaptive processes to the bird's environment. For example, birds differ in average wing length in response to migratory needs (Coyne and Orr, 2004). Birds undergo changes in the shape and color of feathers or body composition, such as fat content (weight). Such morphological changes are usually associated with seasonal activities like breeding, migration status, and diet (Piersma and Drent, 2003).

Birds of prey are characterized by strong feet and claws for grasping and killing, as well as hooked beaks for tearing flesh. These morphological parameters are often adaptations to their lifestyle and are used to describe and classify raptors (Bildstein, 2017). For instance, their leg structure is strong and equipped with sharp claws that aid in hunting (Boal and Dykstra, 2018). The morphology of legs and claws is highly variable among different species, which aids in their classification (Einoder and Richardson, 2007; Fowler *et al*., 2009). The form and function of these structures are generally considered evolutionary adaptations to prey type and size (Ward *et al*., 2002).

There is a significant size difference between the sexes in birds, with females appearing larger than males (Jukema and Piersma, 2006). This difference contributes to females laying larger eggs and being able to incubate them more efficiently than males, while the smaller size of males helps them fly faster (Ohlsson and Smith, 2001; Meiri and Dayan, 2003). Body size is often adapted to prey size, food resources, and habitat type (Millien *et al*., 2006; Lomolino, 2005; Clegg and Owens, 2002). Raptors are highly sensitive to environmental changes as they are often found at low densities and have low reproductive rates (Hoffman and Smith, 2003; Abusharya *et al.,* 2025).

Maintaining constant growth rates of chicks helps their survival and serves as good indicators of food abundance (Remes, 2006; Segura and Palacio, 2022). The variation in growth rates arises from various influences, including the abundance and diversity of food resources and the surrounding environment (Bettega *et al*., 2011;

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Gombobaatar *et al*., 2010). The mass and size of raptor chicks vary based on food type (Bordner *et al*., 2022), and the size and hatching date of eggs significantly affect growth rates (Krist, 2011; Loonstra *et al*., 2018). It is important to recognize that the study of growth rates of raptor chicks is of great importance due to their role as apex predators and as an indicator of ecosystem health (Hernández-Matías *et al*., 2024). The study of growth rates contributes to maintaining the state of ecosystem balance and recognizing environmental changes that may occur in the ecosystem (Santangeli and Girardello, 2021). The female short-toed eagle lays only one egg per year (Mori *et al*., 2017; Naoroji, 2006). The phenotype of the short-toed eagle was described by Alharir (2014), where it was stated that its body length ranges between 62-73 cm, and body weight between 1.5-2.5 kg. The shape of the head is broad, the eyes are large and yellow, similar to owl eyes, the upper parts of the head are brown in color, and the lower parts are white in color, spotted with black.

Through the above, this research aims to determine some morphological measurements of a short-toed eagle chick. Analyze the measurements to determine differences in growth rates of morphological characteristics. And Recognize the relationship between the morphological characteristics of a short-toed eagle chick.

2. Material and Methods:

2.1. Study Areas:

Wadi Al-Naqa Reserve is located within the Al-Jabal Al-Akhdar region in the eastern part of Libya, between longitudes 39" 28 ' 22° and 12" 34' 22° east and between two latitude circles 45" 34' 32° and 31" 47' 32° N. It is bordered on the east by Wadi Bou Massafer, Al-Qubba and Wadi Al-Anjil on the west; the Derna coastal highway near the Mediterranean coastline is its northern border, and the second edge of the Al-Jabal Al-Akhdar is its southern border. The area of the region is about 48.51 km^2, equivalent to 4851 hectares. Wadi Al-Naqa Reserve is spread across many forests of evergreen trees, the most important of which are *Phoenician juniper*, *Arbutus unedo*, *Olea oleaster* and others, in addition to the presence of small shrubs, seasonal and wild plants and grasses (Alkhajkhaj, 2023). The reserve is characterized by a large animal diversity, including species threatened with extinction such as the African golden wolf, the Wildcat, the Greek tortoise and others. It is also characterized by being far from all sources of pollution of various types and forms; all of this helped to create a good natural environment and a suitable climate for the presence of some endangered plant and animal species that are globally classified within the red line, and it is forbidden to establish any activity that may cause damage inside the reserve, such as hunting, cutting trees, lighting fires, etc.

Fig. 1. The geographical location of the study area (Wadi Al-Naqah Reserve).

2.2. Equipment used in the study:

- Nikon P 1000 camera with a zoom lens 125× for distant photography at a distance of 1,500 m.
- HD T70 Campark Trail camera for close and still photography.
- An electronic scale to measure the weight of the chicks.
- A measuring meter to know some morphological measurements of the chicks.

2.3. Method:

This study was conducted over a period of five consecutive years from 2020 to 2024 AD, through field visits to the study area during a period of 10 to 15 days per month at the rate of two visits per month; to record and take morphological measurements of the chick to describe the external characteristics of the chick such as body length, weight, leg length, and claw (Waheed *et al.,* 2021; Wiklund, 1996). One nest was selected annually from among seven active nests in the study area. The nests were selected at random to avoid repeating the same nest, given that most of the nests were located on trees growing on rugged, steep slopes.

Fig. 2. Method for Taking Morphological Measurements.

2.4. Statistical data analysis

SPSS version 16.0 was used to analyze the statistical data; Least Significant Difference (LSD) analysis was used for morphological measurements of short-toed eagle chicks, and Pearson correlation coefficient was used to find out the relationship between morphological traits of the chicks.

3. Results

Chick morphological measurements (length, width, weight, claw length, leg length)

To find out the results of the morphological measurements of a short-toed eagle chick, the measurements were interpreted by analyzing paired comparisons (Least Significant Difference) to find out the morphological differences during the time period of each year, and the results were as follows:

1- Pairwise comparisons of short-toed eagle chick length on the time period variable:

- Hypothesis: There are no significant differences between chick length means attributable to the time period variable.

Table (1): Tests of pairwise comparisons of short-toed eagle chick length on the time period variable

Time Period		Mean Difference	Standard Errors	Statistical Significance
First 15 days	Second 15 days	-6.40	0.68799	0.000
	Third 15 days	-19.00	0.68799	0.000
Second 15 days	Third 15 days	-12.60	0.68799	0.000

From Table (1), we observe that there are significant differences (α =0.05) between the mean chick length attributed to the time period variable. The chick length increases by an average of 6.4cm in the second 15 days compared to the first 15 days, while it increases by an average of 19cm in the third 15 days compared to the first 15 days. The chick length increases by an average of 12.6cm in the third 15 days compared to the second 15 days.

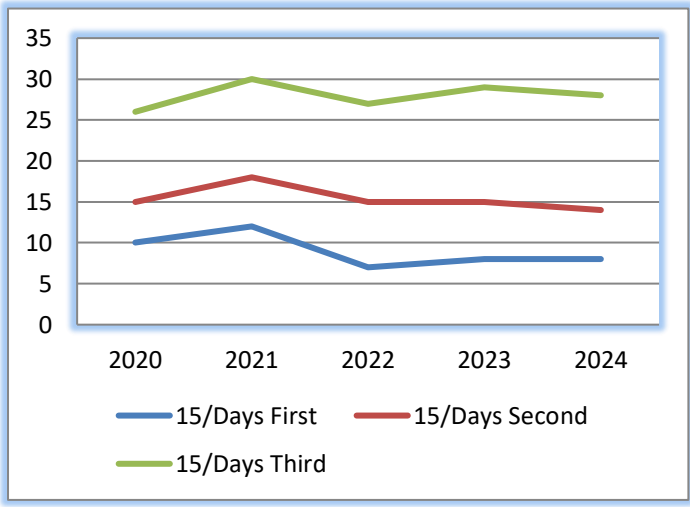

Fig. 3. The average length of a short-toed eagle chick

We note from Fig. 3 that the largest increase in the average length of the chick was between the second 15 days and the third 15 days with an average of 12 cm, while the average increase in its length does not exceed 6 cm between the first 15 days and the second 15 days. We also note that the year in which the chick increased in length is 2021, which was in the third 15 days, where its length reached 31cm, while the lowest length of the chick was in 2022, during the first 15 days, where it did not exceed 4 cm.

2- Pairwise comparisons of the width of a short-toed eagle chick attributed to the time period variable:

- Hypothesis: There are no significant differences between the mean chick widths attributed to the time period variable.

Table (2): Tests of pairwise comparisons of short-toed eagle chick widths for the time period variable

Time Period		Mean Difference	Standard Errors	Statistical Significance
First 15 days	Second 15 days	-4.000	0.30551	0.000
	Third 15 days	-15.200	0.30551	0.000
Second 15 days	Third 15 days	-11.200	0.30551	0.000

From Table (2), we observe that there are significant differences (α=0.05) between the means of chick width attributed to the time period variable. The chick width increases by an average of 4cm in the second 15 days compared to the first 15 days, while its width increases by an average of 15.2cm in the third 15 days compared to the first 15 days, and the chick width increases by an average of 11.2cm in the third 15 days compared to the second 15 days.

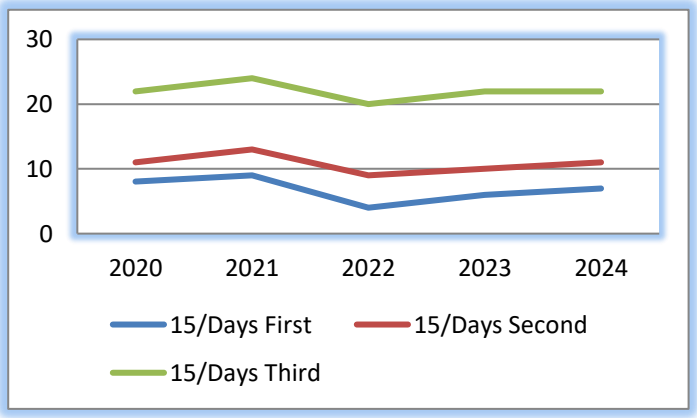

Fig. 4. Average width of a short-toed eagle chick

We can see from Fig. 4. that the least increase in the average width of the chick was during the time period from the first 15 days to the second 15 days, while the most increase was from the time period from the second 15 days to the third 15 days. We can see from this figure that the chick increased its width by an average of 11cm during the period from the second 15 days to the third 15 days, while the average width does not exceed 4cm between the first and second 15 days. The year 2021 is the year in which the chick's width increased the most, which was during the third 15 days, where its width reached 24 cm, while it was the least in 2022 during the third 15 days, where its width did not exceed 20 cm.

3- Pairwise comparisons of the weight of a short-toed eagle chick attributed to the time period variable:

- Hypothesis: There are no significant differences between the mean chick weights attributed to the time period variable.

Table (3) Tests of pairwise comparisons of short-toed eagle chick weight for the time period variable

Time Period		Mean Difference	Standard Errors	Statistical Significance
First 15 days	Second 15 days	-229.6	174.3379	0.224
	Third 15 days	-1383.6	174.3379	0.000
Second 15 days	Third 15 days	-1154.0	174.3379	0.000

From Table (3), we observe that there are significant differences (α=0.05) between the means of chick weight during the first 15 days and the second 15 days. The weight of the chick increases by an average of 229.6g in the second 15 days compared to the first 15 days. There are also significant differences (α=0.05) between the means of chick weight during the first 15 days and the third 15 days, where the weight of the chick increases by an average of 1.383 kg in the third 15 days compared to the first 15 days, and an average of 1.154 kg in the third 15 days compared to the second 15 days. From the above, it is clear that the weight of the chick increases only by 1.154 kg during the first month of life, while it increases by 1.384 kg during 45 days compared to its weight during the first 15 days, which did not exceed 230 g. The average weight of the chick increases by 1.384kg.

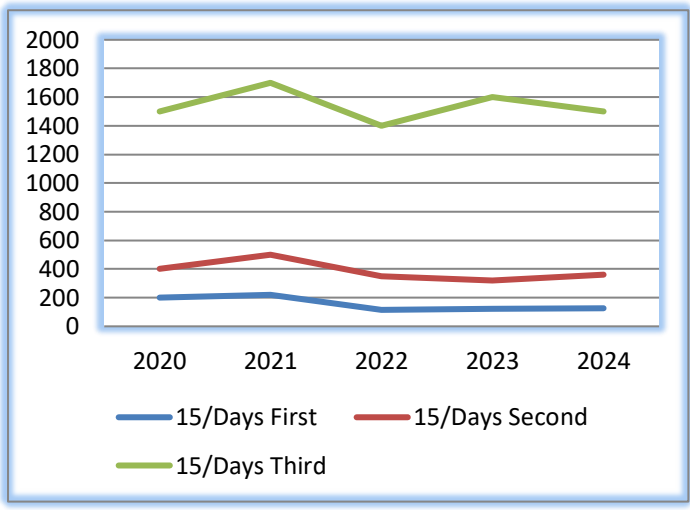

Fig. 5. Average weight of a short-toed eagle chick

From Figure (5), we can see that the largest increase in chick weight was during the third 15 days in 2021, with an average weight of 1.7 kg. We can also say that the chick gained weight significantly during the third 15 days, and the average weight gain during the first 15 days and the second 15 days was almost constant during the study years.

4- Pairwise comparisons of short-toed eagle claw length attributed to the time period variable:

- Hypothesis: There are no significant differences between chick claw length means attributable to the time period variable.

Table (4): Tests of pairwise comparisons of short-toed eagle chick claw length for the time period variable

Time Period		Mean Difference	Standard Errors	Statistical Significance
First 15 days	Second 15 days	-0.600	0.17321	0.009
	Third 15 days	-1.200	0.17321	0.000
Second 15 days	Third 15 days	-0.600	0.17321	0.009

From Table (4), we can see that there are significant differences (α=0.05) between the averages of the chick's claw length attributed to the time period variable. The chick's claw length increases by an average of 0.6 cm in the second 15 days compared to the first 15 days, and increases by an average of 0.6cm in the third 15 days compared to the second 15 days, while it increases by an average of 1.2cm in the third 15 days compared to the first 15 days, which shows that the chick's claw length increases by 0.6cm every 15 days.

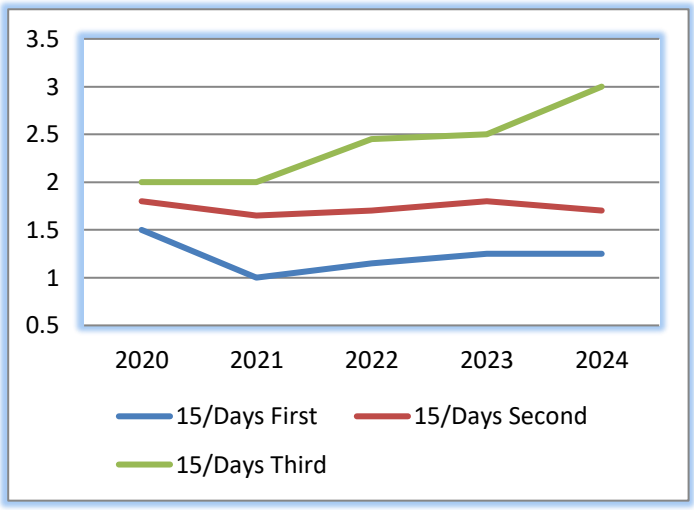

Fig. 6. Average claw length of a short-toed eagle chick

We note from Fig. (6) that the longest claw of the chick was during the third 15 days in the year 2024 with an average length of 2.7cm. The claw length increases significantly in the third 15 days in the years 2023 and 2024, and the rate of increase in claw length during the second 15 days during the study years is constant, reaching 1.75 cm. The lowest average claw length during the first 15 days in 2021, where it did not exceed 1 cm.

5- Pairwise comparisons of leg length of a short-toed eagle chick attributed to the time period variable

- Hypothesis: There are no significant differences between the means of chick leg lengths attributed to the time period variable.

Table (5): Tests of pairwise comparisons of short-toed eagle chick leg length for the time period variable

Time Period		Mean Difference	Standard Errors	Statistical Significance
First 15 days	Second 15 days	-6.600	0.8000	0.000
	Third 15 days	-11.60	0.8000	0.000
Second 15 days	Third 15 days	-5.000	0.8000	0.000

From Table (5), we observe that there are significant differences (α=0.05) between the mean length of the chick's leg attributed to the time period variable. The chick's leg length increases by an average of 6.6cm in the second 15 days compared to the first 15 days, and increases by an average of 11.6cm in the third 15 days compared to the first 15 days, and increases by an average of 5 cm in the third 15 days compared to the second 15 days. The average length of the chick's leg increases by 5.8cm every 15 days.

We can see from Figure (7) that the greatest increase in the average length of the chick's leg was between the first 15 days and the second 15 days, as it increased its leg length by an average of 6.6 cm, while it did not exceed 5 cm between the second 15 days and the third 15 days. The year 2021 is the year in which the chick's leg length increased the most, reaching 19 cm.

- Type and strength of relationship between morphological characteristics of a short-toed eagle chick:

Pearson's correlation coefficient was used to determine the type and strength of the relationship between length, width, weight, claw length, and leg length of the short-toed eagle chick.

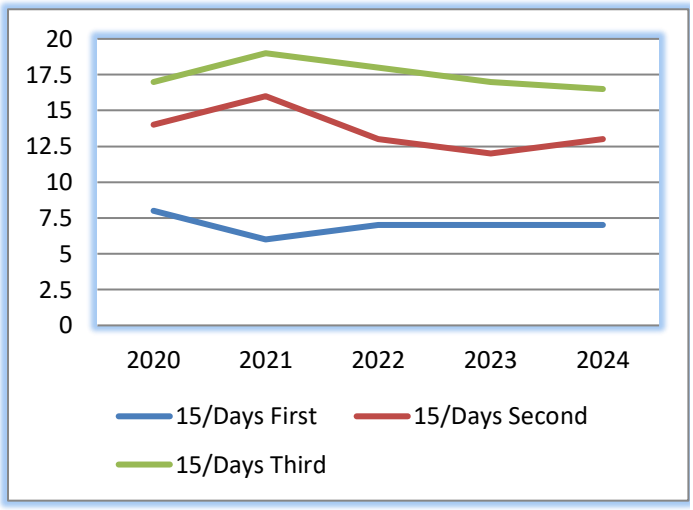

Fig. 7. Average leg length of a short-toed eagle chick

Table (6): Correlation coefficients between the morphological characteristics of the short-toed eagle chick.

Variable	Length	Width	Weight	Claw length	Leg length
Length	1	**0.988	**0.975	**0.865	**0.944
Width	**0.988	1	**0.982	**0.834	**0.912
Weight	**0.975	**0.982	1	**0.826	**0.887
Claw length	**0.865	**0.834	**0.826	1	**0.908
Leg length	**0.944	**0.912	**0.887	**0.908	1

Table (6) shows that there is a positive direct correlation (α=0.05) between the length of the chick and each of its width, weight, paw and leg length, and the value of the correlation coefficient is (r=0.944, r=0.865, r=0.975, r=0.988), which is a strong linear relationship. There is a positive direct correlation between the width of the chick and its weight, paw and leg length, and the value of the correlation coefficient is (r=0.912, r=0.834, r=0.982), which is a strong positive correlation. There is a positive direct correlation between the weight of the chick and the length of its claw and leg, and the value of the correlation coefficient is (r=0.887, r=0.826), which is a strong positive correlation. There is also a positive direct correlation between the length of the claw and the length of the leg of the chick, and the value of the correlation coefficient is (r=0.908), which is a strong positive correlation.

6. Discussion

This study was conducted in Wadi Al-Naqa Reserve in the Al-Jabal Al-Akhdar in northeastern Libya, during the incubation and nesting period for five consecutive years from 2020-2024. The study recorded preliminary data on some morphological characteristics and growth development of the short-toed eagle chick.

The results of this study show that the growth rates of short-toed eagle chicks may vary from year to year and from nest to nest. This variation may be due to several factors, such as diet, climate, or differences related to the timing of incubation and hatching, as well as the age of the female.

One of the traditional methods used to assess morphological variations is the taking of anthropometric measurements, due to the accuracy of its data and ease of conducting it, as these measurements are regularly performed in most scientific studies related to ornithology (Eck *et al*., 2011). By taking morphological measurements of the short-toed eagle chick, the results of this study indicate that the highest weight reached by the chick was 1.700 kg during 45 days after hatching. These results are consistent with the study of Pavón *et al*. (2010), which indicated that the weight of the eagle reached 1.686 kg for the male and 1.945 kg for the female.

The results showed that the maximum length of a short-toed eagle chick in this study reached 31cm and its width reached 24 cm at the age of 45 days. In contrast, a study by Hadi *et al*. (2022) reported the average length of an adult short-toed eagle as 62.8 cm and its width as 52.5 cm. This discrepancy is expected, as the current study focused on chicks rather than adult eagles. Additionally, our results indicated that the chick's leg length reached 19cm and its claw length was 2.7 cm by day 45.

The results of the study showed that the growth rate of the chick increases significantly during the third 15 days after hatching, equivalent to 45 days of the chick's age. This is consistent with the study of Bazarbekov *et al*. (2023), who stated that the eagle chick flew for the first time approximately 46 days after hatching. Through the results of this study, it is clear that there is a strong direct relationship between the morphological characteristics of a short-toed eagle chick.

4. Results

The findings of this study can be summarized as follows:

- The study of morphological characteristics helps to know the nature of the growth and development of the structure of the short-toed eagle chick during the incubation period.
- The growth rate of the chick increases significantly when the chick reaches 45 days, which is a good indicator of the nature and type of food in the study area.
- There is a strong positive correlation between the morphological characteristics of a short-toed eagle chick.

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